OUR SIDEREAL SYSTEM, AND THE DIRECTION AND DISTANCE TO ITS CENTRE.

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I. The Form of our Sidereal System.—Before we can find the centre of an object, we must have a knowledge of its form. The form of our system is determined by the ring of the galaxy; because it is computed to contain eighteen millions of stars, while all the other stars situated around and within that ring are supposed to number only about two millions. The best observers declare that they can look fairly through the galaxy, and see beyond only the black ground of empty space. Its ring form is further proved by the fact that the great mass of its stars are of the same small magnitudes, from the 9th to the 12th. If it were merely the appearance of a *stratum* of stars extending outward from our own vicinity, it would contain many more stars of large magnitudes, and these magnitudes would regularly and gradually decrease in size from their increasing distances. But no such appearance is presented. Therefore, as Sir John Herschel announces, "it is not a *stratum*, but an *annulus*."

In the general direction of the galaxy, though situated far beyond, there are very many easily resolvable nebulæ, which are unique among all nebulæ, from their very irregular forms and aspects. From their appearances and positions, and resolvability, they must be members of our own sideral system, and they occupy the same relative position to the galaxy, as the systems of Jupiter, Saturn, and Uranus hold to the ring of the asteroids.

In some places observers cannot apparently see through the galaxy; stars, or rather nebulæ, appear beyond one another indefinitely. These appearances are explained by the resolvable nebulæ just mentioned, which are the extremely distant members of our system, and by the irresolvable nebulæ in the same direction, though far beyond, which are independent sidereal systems. The two seem to make a continuity of stars. Mere vision in such cases fails to distinguish these distant sidereal systems from the outlying members of our own system; the same as Saturn and Sirius when side by side, seen by mere vision, seem to be equally distant. Irresolvability is at present a decisive test between the

outlyers of our own system, and other independent sidereal systems.

That our sidereal system has definite bounds, we may believe from the definite boundaries of other distant sidereal systems. Often they are regularly round or elliptical; and even those with irregular contours may have their stars to revolve in nearly circular orbits; the same as our solar system must appear to distant observers to be extremely irregular in contour, although its revolutions are nearly circular.

Neither is our opinion of the definite boundary of our system disturbed by the appearance of new stars with every new power added to the telescope. These newly-discovered stars may be its smaller members, and comparatively near, and visible only by high powers.

Nor is it an argument against the ring form of the galaxy, because it is broken by a slight transverse rift in the southern hemisphere. My recollections are distinct that this rift is exceedingly narrow, hardly observable, and smaller by far than the longitudinal rifts in both hemispheres.

Therefore all objections are easily answered, and we have solid grounds to conclude that our sidereal system is round, and in the main, disk-like in form, with the vast majority of its stars in or near the plane of the galaxy. The ring form of the chief mass of our system, is confirmed by the existence of other rings of stars, as the annular nebulæ, the ring of the asteroids, and the rings of Saturn, composed, there is good reason to believe, of very little stars, the majority not larger than meteorites.

II. The Position of the Centre of Gravity.—From the form of our sidereal system the conclusion is clear and irresistible that the centre of gravity of the system must lie in the plane of the galaxy. It is also equally clear that this centre must be situated in the centre of that plane. Because the stars in general are equally numerous, and equally large and bright in all extended regions of that ring. They appear a little brighter towards the southern pole; but this seems an indication that our own position is a little nearer that side of the galactic ring.

III. All the Stars of our Sidereal System Revolve with high Velocities around its Centre of Gravity.—It was formerly supposed that the vast distances between the stars cut off this intergravitating force. Newton, in his Principia, uses this

language: "The fixed stars, therefore, being at such vast distances from one another, can neither attract each other sensibly, nor be attracted by our sun." This opinion was generally held among his followers, one of whom has remarked: "So remote are the nearest of the fixed stars, that it may be doubted whether the sun has any sensible influence on them." It is remarkable that the thought occurred to no astronomer to calculate the force of gravity from our sun on the fixed stars, until more than a quarter of a century after the distances of some of these stars had been approximately discovered. Then this was first done by myself, and the amount of this force was found to be surprisingly large. To present an impressive and graphic view of that amount, I brought it out in terms of the velocity around our sun required for gaining a centrifugal force so great as to prevent a revolving body from falling in the sun. I employed two methods of demonstration quite independent of each other, and by both the same results were obtained. As these methods have already been stated in the "Origin of the Stars," they need not be repeated here. By them it was proved that our sun acts so powerfully on Alpha Centauri that, if there were no other influence, Alpha Centauri would have to revolve around our sun at the rate of 145 miles an hour to gain a counterbalancing centrifugal force. That star, judging from its distance, and its amount of light, must be two and a third times greater than our sun. Therefore its power of gravity alone on our sun is such that, without any other influence, our sun must revolve around it at the rate of 222 miles an hour to gain a counterbalancing centrifugal force. Judging from its distance and its light, Sirius is at least sixty times greater than our sun. Therefore our sun would have to revolve around Sirius at the rate of 580 miles an hour to avoid falling into its flames. In all these instances, the gravity of a single star has alone been calculated, and not the combined force of the two.

These velocities impress strongly on our minds the greatness of the force of gravity between the stars of our sidereal system. How inconceivably mighty must be the united force between the twenty millions of stars. How strongly must they all be impelled toward this common centre of gravity. And how swift must be their velocities around that centre to gain a centrifugal equal to the centripetal force. Now, first, we understand the necessity of such high velocities as those of 61 Cygni, and of

Arcturus, and of other stars ; that is, velocities from nearly 2000 to nearly 3000 miles per minute, velocities about double any of those seen among the planets of our solar system.

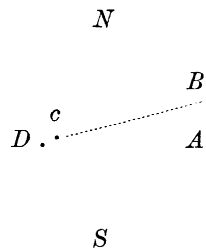
It is evident that the stars of the galaxy must all move in the same direction around in the plane of the galactic ring, otherwise they wound fly off, and soon there would remain no ring.

It is also evident that such rings of stars revolving with high velocities, both in our own and in other sidereal systems—annular nebulæ—coincide perfectly with the nebular theory which teaches the absolute necessity of ring formations abandoned by centrifugal force in high velocities of revolution.

IV. THE DIRECTION FROM OUR OWN POSITION TO THE GALACTIC CENTRE or to the CENTRE OF GRAVITY OF OUR SIDEREAL SYSTEM. —Our own position is certainly on the north side of the galactic plane; that is, on the same side with Ursa Major, and not on the side on which Orion appears. The median line of the galaxy, or its plane, does not coincide with a parallel great circle. Between the two, as projected on the heavens, there is a distance of about 2°, the precise distance being not yet determined within half a degree, more or less. This appears as follows: The median line of the galaxy is distant about 32° from the north pole; but on the opposite side of the heavens it is distant from the south pole only about 27°. Other measurements in other regions, not polar, correspond. This difference of five degrees must be equally divided, and there remains about $2\frac{1}{2}$° as the distance in arc between the median line of the galaxy and a parallel great circle. Our own position therefore is situated, as measured by our great circle, about $2\frac{1}{2}$° away from the galactic plane, and on its north side. We are further confirmed in this conclusion because it explains the fact that more stars are seen in the southern galactic hemisphere than in the northern. Many of these southern stars are really on the north side of the galactic plane, but being ourselves so much further north, they are projected on the southern galactic hemisphere. At first view this seems unlikely, but forthcoming proofs are convincing.

Now, being on the north side of the galactic plane, and if we were equally distant all around from the galactic ring, then the conclusion would be certain that the direction of the centre of the galactic plane, or the centre of gravity of our system, would be *precisely toward the south galactic pole*, that is, at about 119°

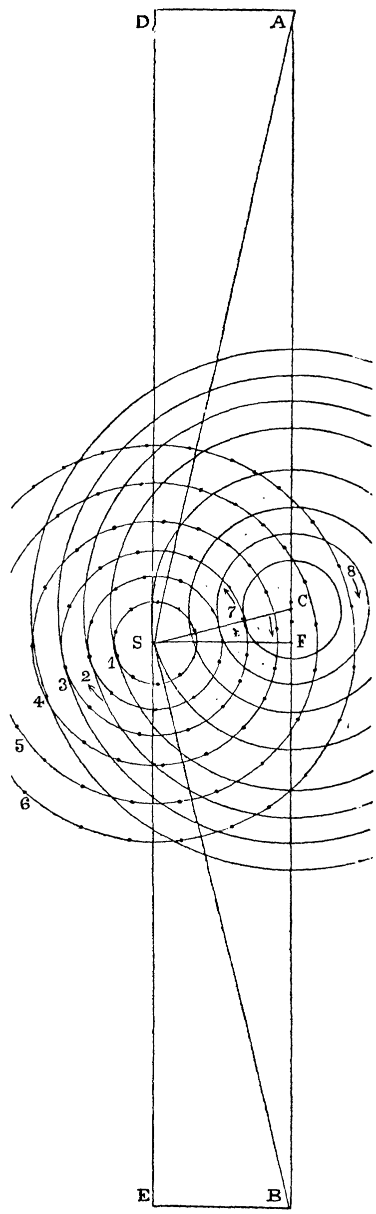
N, P, D, and a little east of the equinoctial colure. In such case there could be no other decision. But because the galactic ring appears a little brighter in the southern regions, it seems probable that we are situated a little nearer towards the southern side of that ring; consequently the galactic centre must be projected on the heavens a little to the north—the geographic north—of the south galactic pole, say in the tail of the constellation Cetus. This northern projection of the galactic centre may be illustrated as follows: Let N be a point in the geographic northern side of the galaxy, S the opposite point in the southern side, A the south galactic pole, and the dot at c the centre of the galactic plane or centre of our system. Then our position at D being a little nearer the southern side of the ring at S, the centre c would be projected on the heavens at B, that is, geographically north from the south galactic pole A. In the figure there is an exaggeration in the position of B to render the principle plain.



Therefore we may affirm, without pretending to absolute precision, that the DIRECTION of the centre of our sidereal system, and consequently its centre of gravity, must lie a little east of the equinoctial colure, and a few degrees north geographically of the south galactic pole; that is, in the tail of the constellation Cetus. It remains now to demonstrate—

V. THE DISTANCE FROM OUR OWN POSITION TO THE GALACTIC CENTRE, OR CENTRE OF GRAVITY OF OUR SIDEREAL SYSTEM.—To find this we have the following data: First, that the median line, or plane of the galaxy, is distant from a parallel great circle $2\frac{1}{2}°$; second, that the distance of the galactic ring from our own position is such as to require 2000 years for its light to reach us. This latter is Sir John Herschel's estimate of its nearest stars of the 9th magnitude. Struve computes that light requires 3400 years to reach us from the galactic stars of the 12th magnitude. In this demonstration the 9th magnitude galactic stars, with the distance for light travel of 2000 years, will be taken. In the figure S represents the position of our sun or our own position. The dotted circles are the distances of the stars of the several numbered magnitudes. A B is the plane of the galaxy, and C its centre. D E is the plane of a parallel great circle. S C is the

distance from ourselves to the galactic centre, or the centre of our sidereal system. $S\ F$ is a line perpendicular to the galactic plane. Our position S is made a little nearer to the geographical southern side of the galaxy at B, for the reason already stated. $D\ A$ is the arc, and $D\ S\ A$ the angle between the galactic plane and a parallel great circle, at present assumed at $2\frac{1}{2}°$. $S\ A\ F = D\ S\ A$. Light requires 2000 years to travel from A to S, or from A to F nearly. Here we have a right-angled triangle with three known elements, namely, $A\ F = 2000$; $S\ A\ F = 2\frac{1}{2}°$; $S\ F\ A = 90°$. From these elements it follows from the most simple of all trigonometrical processes that $S\ F$ equals 87. Therefore it requires light 87 years to pass between ourselves and the plane of the galaxy, or about the same to reach the galactic centre at C. But according to the estimates of astronomers, light requires 85 years to reach us from the stars of the 5th magnitude; therefore the centre of our sidereal system is distant from our own position about as far as the stars of the 5th magnitude.



But the amount of the arc $D\ A$ or the angle $S\ A\ F$ is not yet precisely determined. If it be only 2°, then the distance from the plane of the galaxy is such

that light from there requires 70 years to reach us, and it must lie beyond the stars of the 4th magnitude, as it is drawn in the accompanying figure. If the angle *S A F* equals $1\frac{1}{2}°$, then the light from the region of the galactic plane requires 52 years to reach us, and that plane must lie beyond the stars of the 3d magnitude. And so on, after the following table, where the third column expresses the number of years required for light to reach us from the stars of the several magnitudes, according to Struve, and also from the galactic plane, when the first column expresses the different values of the arc *D A* or the angle *S A F*.

Angle S A F.	Star magnitudes.	Distances in years.
	1	15
$\frac{1}{2}°$		17
	2	28
1°		35
	3	43
$1\frac{1}{2}°$		52
	4	61
2°		70
	5	85
$2\frac{1}{2}°$		87
3°		104
	6	120
4°		140

We have now discovered approximately both the DIRECTION and the DISTANCE to the centre of our sidereal system. I need not at this early day be precise in my statements of either of these elements: these will require the careful observations and measurements of many years. When Copernicus had announced the centre of our solar system, his discovery was not vitiated nor rendered the less valuable because he made such an enormous error about the distance of that centre. Even yet, after the studies of 10 generations, that is, of 333 years, astronomers are still endeavoring to find more nearly the distance to the centre of our solar system. These round numbers just named measure the long flight of time which has intervened between the discoveries of these two centres, the centre of our solar and the centre of our sidereal system. In attaining precision in the distance to the centre of our sidereal system, the first element to be determined is the arc *D A*, or the angle *S A F*. Its nearest value seems to me at present to be 2°,

and the figure is drawn on that supposition, locating the sidereal centre between the stars of the 4th and 5th magnitudes.

In addition to the data contained in the five sections already given, our present determination of the direction and distance is confirmed by the observed movements of the stars. Hitherto, the proper motions of the stars, amounting to nearly 2000, have presented the most wild and disorderly confusion. Nothing can be more hopeless and forbidding than an attempt to find our sidereal centre from the study of these motions. But our present determination of that centre shows the causes of this apparent confusion. It is because we are situated on one side of our system, far outwardly and away from the centre, with some stars interior and other exterior to us; precisely the same reason why the motions of the planets seemed so tangled before the discovery of the centre of our solar system. I will here point out the operations of this cause in detail, along with other causes of this apparent disorder.

1. In our figure the two stars within the dotted circles, marked with arrows at 2 and 7, move in the direction of the arrows. On the face of the heavens, or on a celestial globe, they seem to move around in contrary directions, the same as they seem to move in our figure in contrary directions around our position at *S*. But in reality they both move in the same direction around our sidereal centre at *C*.

2. The stars at 7 and 8, marked with arrows, seem, from our position at *S*, to move in contrary directions, but in truth they both move in the same direction around the sidereal centre at *C*.

3. Our sun's motion must give apparent motions to many stars, and some of these may be contrary to their real motions, the same as our earth gives retrograde motions to the planets. To separate these apparent from their real motions will be a task of many years, even after we learn the true direction of the sun's motion.

4. As our sun is on the north side of the galactic plane, and nearly equidistant from the galactic ring all around, it follows that the plane of his orbit is nearly, perhaps quite, at right angles to the galactic plane. It is evident also that thousands of other stars move in planes either at right angles, or highly inclined, to the galactic plane. Hitherto all this has been a source of perplexity, but now we may begin to lay down the lines of their nodes

on the galactic plane, and make real progress in sidereal astronomy, evolving beautiful order out of this apparent confusion.

5. In a system like our solar system, with a large central orb, and all the stars nearly in the same plane, it is generally conceded that the revolutions of these stars must be around in the same direction; contrary motions being incompatible with stability. But this cannot be affirmed of our sidereal system, which has no large central and controlling orb, where the stars are very far apart, and where their orbits are highly inclined in opposite directions, nearly or quite at right angles to the galactic plane, and so have come to move in opposite directions around the sidereal centre. This has occurred to thousands of stars in our sidereal system. It has occurred also in other far distant sidereal systems, for they are globular in shape. If only a few appeared round we might suppose them discoid, with the planes of their disks perpendicular to their lines of sight. But such large numbers of round systems argue globularity of form.

6. My discovery of the intergravitation among the members of our sidereal system, as stated in Section III. of this paper, aids to prove that collisions must be impossible, or very rare between the members of our system, even when they move in opposite directions. When two stars are meeting from opposite directions, they are under the influence through gravity of all the neighboring stars, drawing them from the line toward each other's centres of gravity, and therefore the chances are infinite against their moving towards each other's centres of gravity. They must approach each other, not directly, but obliquely ; they may pass so near to each other as to remain forever under the power of their mutual gravitation, revolving around their common centre of gravity, and becoming a double star. Hence, the wonderful spectacle in the heavens of ten thousand double and multiple stars, with many more still to be discovered. A pair of stars may attract a third, and a fourth, and indeed a larger group like the Pleiades and Coma Berenicis, and the clusters in Hercules. A considerable cluster by their united gravity might draw to themselves all or nearly all the neighboring stars, leaving nearly vacant spaces around the clusters. Whenever Sir William Herschel, in his sweeps of the heavens, came upon one of these vacant spaces poorly furnished with stars, he was sure to look out for a cluster, or nebulous looking mass, consisting of the stars collected to-

gether from the nearly vacant spaces. We know that binary systems of stars may have proper motions, and so may larger groups.

7. In constellations like Ursa Major, and Cassiopeia, and others, the motions of their individual stars around the centre of gravity of the constellation, may obscure or hide their motions around the centre of our sidereal system. The revolutions of the satellites of Jupiter and Saturn and Uranus have more rapid velocities around their primaries than the velocities of those planets around the sun. A like state of things, though not so extreme, may exist in a constellation. According to Struve and others, the distance of second magnitude stars is such as to require their light 28 years to reach us. If in a triangle we take this number for each of the two sides, and for the included angle the divergence between two adjacent stars in Ursa Major, we are surprised on computing the third side of our triangle, to find how near those stars must be together. Therefore knowing the gravitation of our sun on our neighboring stars, we must conclude that in a cluster like Ursa Major, the revolutions around its centre may greatly modify and perhaps reverse for a time, the proper motions of those stars around the centre of our system.

8. As our sun's motion may give apparent retrograde motions to some of the stars, it is of the first importance in sidereal astronomy to learn the point to which our sun is tending. In our search for this we may now confine our endeavors to a narrow zone in the heavens. The sun's motion must be nearly at right angles to the line drawn to the centre of our system. This motion therefore must be toward some point in the zone of the galaxy. The method hitherto employed to ascertain the direction of our sun's motion, is very deceptive. As we travel through a wood the trees appear to grow wider apart in front of us, and closer together behind us. The same principle has been applied to the stars, comparing them with the trees. But how could such appearances, wider and closer, occur among the trees, if those trees were all in motion as rapidly as ourselves? The other stars are moving like our sun. Therefore this tree method of learning our sun's motion, is liable to grave objections.

9. The zone of the galaxy varies in breadth on the face of the heavens, but on an average it is from eight to ten degrees wide. If we be $2\frac{1}{2}°$ from its median line or plane, then this wide band

stretches not only over our own position, but over all the stars of the first and second magnitudes in the direction away from the galactic plane, and also on the other side of that plane far beyond the stars visible to the naked eye. Where the zone of the galaxy is 8° wide, then, calculating from its distance, light requires 280 years to cross that zone. And where it is 10° wide, light requires 350 years to cross it. When we look at right angles away from the plane of the galaxy to the distant stars of the sixth magnitude, and also in the opposite direction on the other side of the galaxy to the distant sixth magnitude stars, and then look up at the galaxy itself, we see apparently a narrow milky band, but it is broader than the entire distance between the opposite stars of the sixth magnitude.

The other dimension of the galaxy at right angles to this, that is, the distance from its nearer to its further or outer surface, is probably four or five times greater. Its nearer stars, those of the ninth magnitude, require 2000 years for their light to reach us, but its more distant, those of the twelfth magnitude, require 3400 years. Therefore the difference of 1400 years is required for the passage of light from its more distant to its nearer stars. Considering the wide space existing within these dimensions, we cannot say that the galactic stars are nearer together than our sun and its neighboring stars. Moreover the specific gravity of the four outer planets of our solar system is many times less than that of the four inner planets. Saturn, for instance, is nine times lighter than Mercury. In like manner the galactic, or the outer stars of our sidereal system, may be many times lighter than our sun and his neighboring inner stars. From both these causes, distance apart and lightness, gravitation between the galactic stars may be less than that between our sun and his neighboring stars. This aids to understand why, from their apparent nearness together, the galactic stars are not brought by gravity in contact, or in very closely revolving systems, like binary stars.

10. By assuming with Herschel that the nearest part of the galaxy requires 2000 years for its light to reach us, we may then calculate its circumference, or the orbits of its stars, and the time required for those stars to make one revolution in their orbits. A star moving at the rate of 3000 miles per minute, about like that of Arcturus, must require 50,000,000 years for a single revolution around the sidereal centre. A star revolving at the rate of 2000

miles per minute, about like that of 6 Cygni, requires 75,000,000 years. And a star moving at the rate of 1000 miles per minute, about like that of our earth around the sun, requires 150,000,000 years for one revolution around the sidereal centre!

Assuming the very probable estimate of 2° between the galactic plane, or median line, and a parallel great circle, then 70 years are required for the passage of light from our sidereal centre to ourselves, and the following table gives the times for a single revolution of our sun, around that centre, at the three different velocities above recorded.

3000	miles	per	minute,	1,760,000	years	for	one	revolution.
2000	"	"	"	2,640,000	"	"	"	"
1000	"	"	"	5,280,000	"	"	"	"

These almost endless periods teach some practical lessons. One is that the direction of our sun's motion for two or three centuries must be sensibly toward the same point in the heavens, or very nearly. If a star in the galaxy performs a revolution in 50,000,000 years, that is, with the velocity of 3000 miles per minute, then about 40 years are necessary for it to move through one second of arc, the smallest quantity measurable in astronomy. That is, if the position of a galactic star be taken and recorded with the most refined accuracy, then it will not be until the next generation of astronomers that the movement of the star can be recognized. If the velocity of the star be 2000 or 1000 miles per minute, then the time required to move through one second of arc must be in one case 60 and in the other case 120 years! No wonder that we cannot tell in which direction the Milky Way revolves. From the well-established intergravitation of the stars, we are sure that it must wheel around in its mighty circle, but we know not which way the wheel turns. This want of apparent motion in the galactic stars is proof positive of their vast distance. It confirms the same conclusion of astronomers founded on the smallness of this magnitude. We now see in a strong and clear light the importance of having portions of the galaxy mapped out, and their positions determined with the closest exactness, so that coming generations of astronomers may learn which way around the great Milky Way revolves.